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John M. McGee
NASA Johnson Space Center
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FLUIDS MANAGEMENT TECHNOLOGY

NASA Lyndon B. Johnson Space Center — Engineering and Development Directorate

FLUIDS MANAGEMENT TECHNOLOGY	PROPULSION AND POWER DIVISION	
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TECHNOLOGY BACKGROUND

- APOLLO
  - ELECTRIC POWER-CRYOGENIC HYDROGEN, OXYGEN-SUPERCRITICAL (SINGLE PHASE)
  - RCS (REACTION CONTROL SYSTEM) HYPERGOLIC PROPELLANTS, DIAPHRAGM EXPULSION
  - OMS (ORBITER MANEUVERING SYSTEM) - HYPERGOLIC PROPELLANTS, SETTLING BY RCS
  - S IV B UPPER STAGE - TRANSLUNAR IGNITION, RCS SETTLING OF SUBCRITICAL CRYOGENICS
- VIKING
  - PROPULSION - HYPERGOLIC, OPENVANE CAPILLARY ACQUISITION
- CENTAUR
  - PROPULSION - RCS SETTLING OF SUBCRITICAL CRYOGENICS

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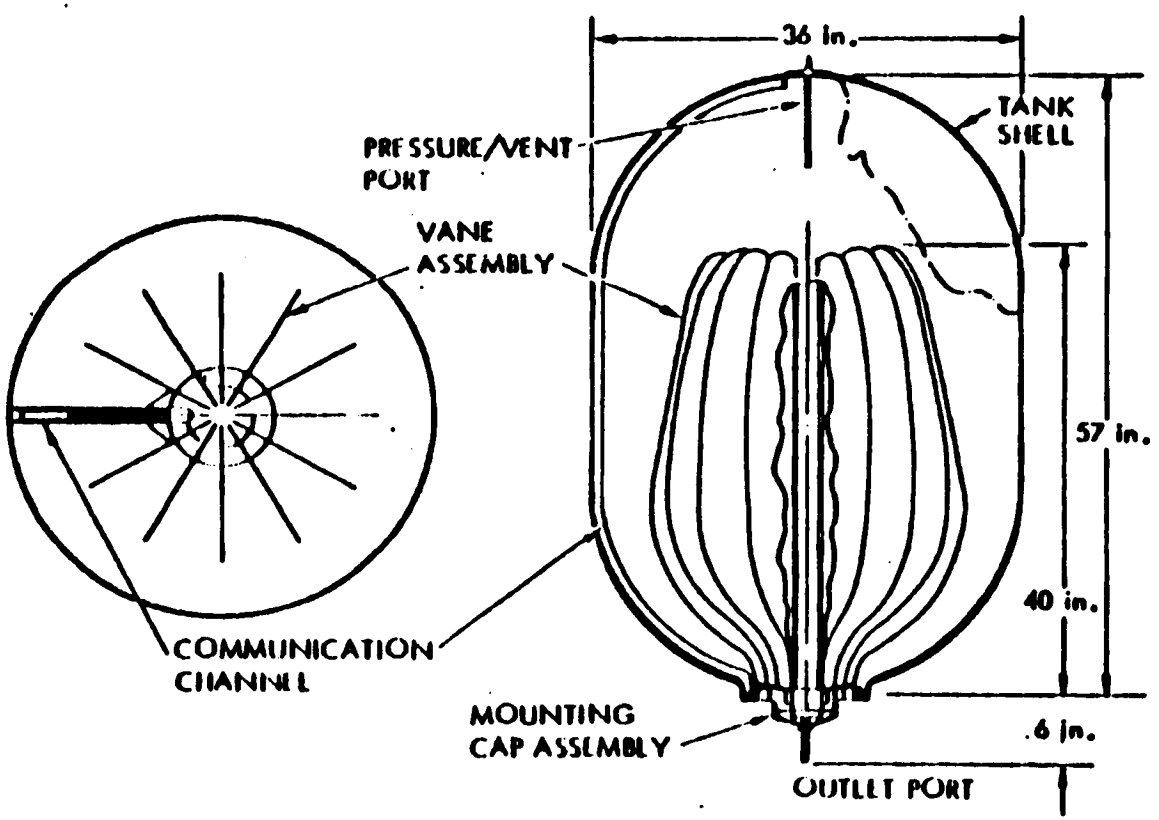
VIKING ORBITER TANK AND PROPELLANT MANAGEMENT DEVICE



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CURRENT TECHNOLOGY (SHUTTLE)

- ELECTRIC POWER - SUPERCRITICAL CRYOGENICS
- RCS - HYPERGOLICS, CAPILLARY SCREEN ACQUISITION
- OMS - HYPERGOLICS, CAPILLARY SCREEN ACQUISITION
- AUXILLIARY POWER UNIT - HYPERGOLIC, DIAPHRAGM EXPULSION

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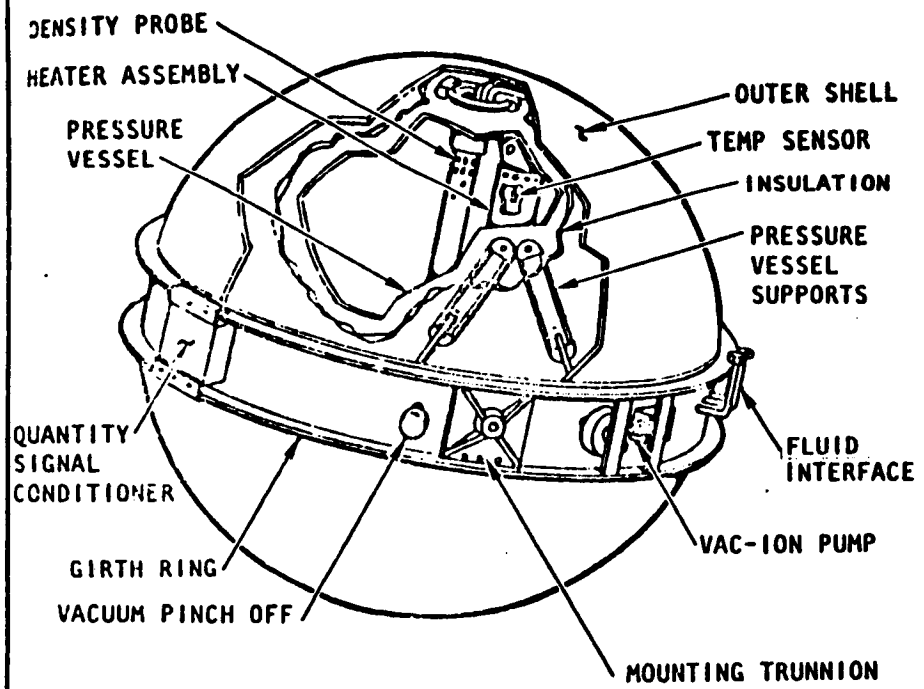
ORBITER PRSA LH_2 TANK



TANK CHARACTERISTICS

- PRESSURE VESSEL
  - MAX OPER PRESS. 315 PSIA
  - MATERIAL 2219 AL
  - ID 41.5 IN.
  - VOL 21.4 CU FT
  - WALL THICKNESS 0.112 IN.
  - SUPPORT TENSION SUSPENSION STRAPS
- INSULATION — DOUBLE SILVERIZED MLI/NYLON NET SPACERS
- VAPOR COOLED SHIELD — —
- TANK MOUNTING — 3-POINT TRUNNION SUPPORTS THROUGH GIRTH RING

HEAT LEAKAGE RATE-BTU/HR (QUAL DATA)

	GROUND	SPACE
• NON-VENTED	26.5	13.5
• VENTED	16.5	5.0

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FUTURE MISSIONS

- SHUTTLE/EXPENDABLE ORBITAL TRANSFER VEHICLE (OTV)
- SHUTTLE/REUSABLE (SPACE BASED) OTV RESUPPLY OF PROPELLANTS & CONSUMABLES
- SHUTTLE/SPACE STATION RESUPPLY OF CONSUMABLES & PROPELLANT FOR OTV
- SHUTTLE/UNMANNED SATELLITE RESUPPLY OF CONSUMABLES
- SPACE STATION/UNMANNED SATELLITE RESUPPLY OF CONSUMABLES
- SPACE STATION/OTV RESUPPLY OF CONSUMABLES AND PROPELLANT
- OTV/GEO STATION RESUPPLY OF CONSUMABLES

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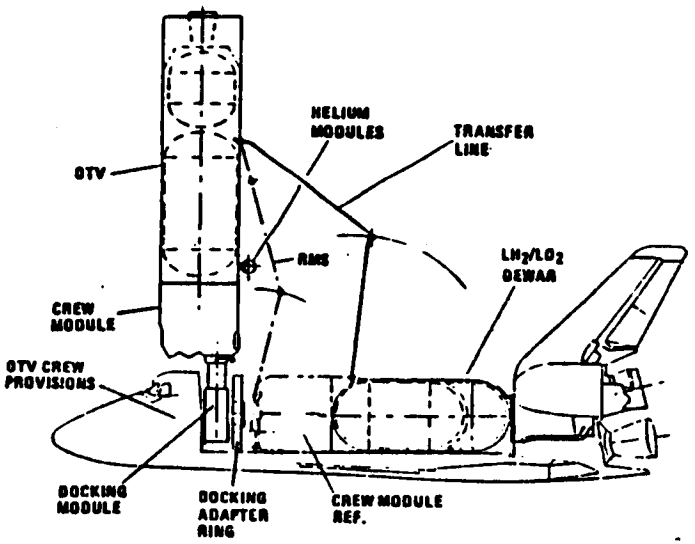
ORBITER TO OTV RESUPPLY

TECHNICAL CONSIDERATIONS

- PROPELLANT TRANSFER EFFICIENCY
  - ▲ SUPPLY TANK WEIGHTS
  - ▲ SUPPLY TANK RESIDUALS
  - ▲ OTV FILL LOSSES
  - ▲ ORBIT STAY-TIME LOSSES
- OPERATIONS
  - ▲ INSULATION
  - ▲ PROPELLANT TRANSFER
  - ▲ PROPELLANT ACQUISITION



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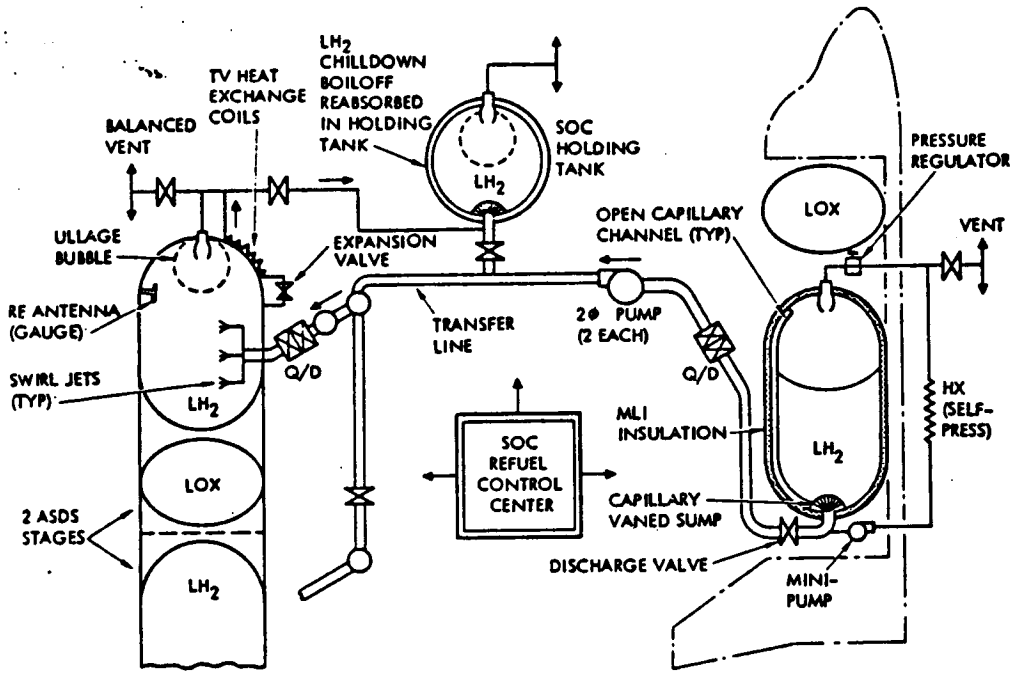
ROCKWELL SOC REFUELING SCHEMATIC



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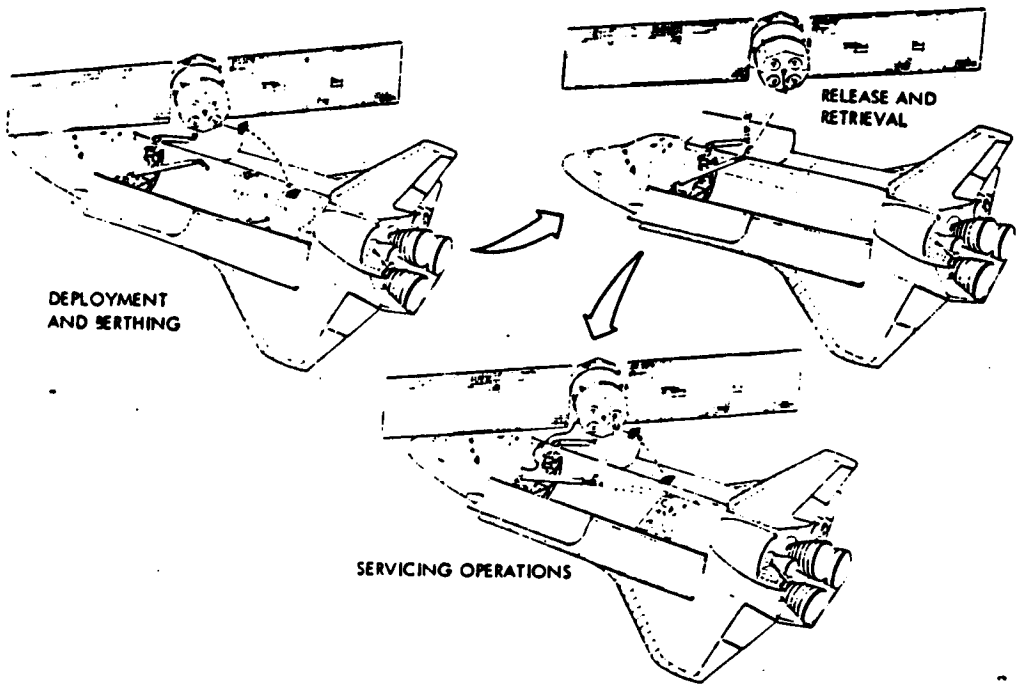
SPACE PROCESSING FACILITY ORBITER SERVICING



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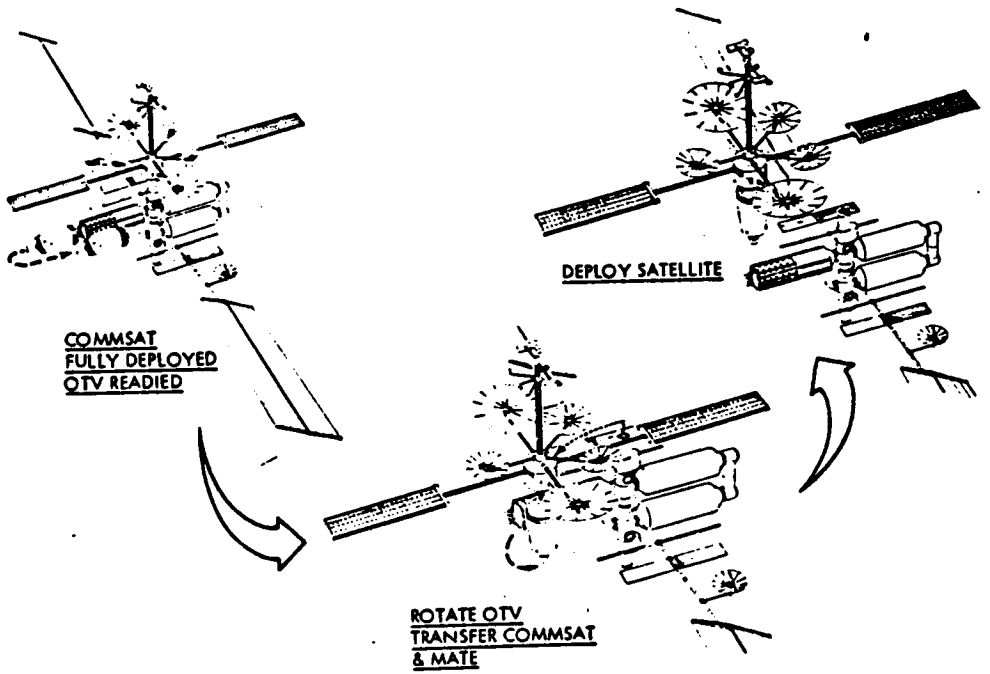
COMMSAT/OTV MATING & DEPLOYMENT SCENARIO



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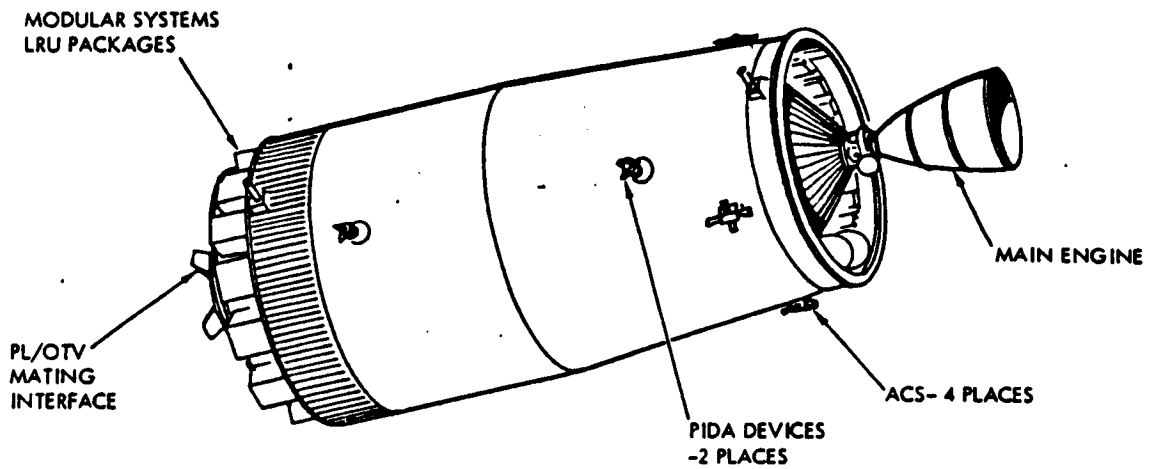
ORBIT TRANSFER VEHICLE (OTV)



- REFUELING OF A SPECTRUM OF PROPELLANTS- LO_2/LH_2 ; HYDRAZINE; He & GN_2
- EXTENSIVE SERVICING & MODULE EXCHANGE OPERATIONS ARE REQUIRED
- FREQUENT VISITS TO SOC

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FLUID MANAGEMENT REQUIREMENTS FOR NEW TECHNOLOGY

- SHUTTLE EXTERNAL TANK (ET) PROPELLANT SCAVENGING (A PRIMARY SOURCE OF SUBCRITICAL CRYOGENICS)
- ON-ORBIT TRANSFER OF SUBCRITICAL CRYOGENICS AND HYPERGOLICS
- LIQUID PHASE ACQUISITION FOR PROPULSION (CRYOGENIC)
- SUBCRITICAL CRYOGENIC GAS DELIVERY
- LONG TERM STORAGE
- QUANTITY, QUALITY, AND FLOW RATE MEASUREMENT

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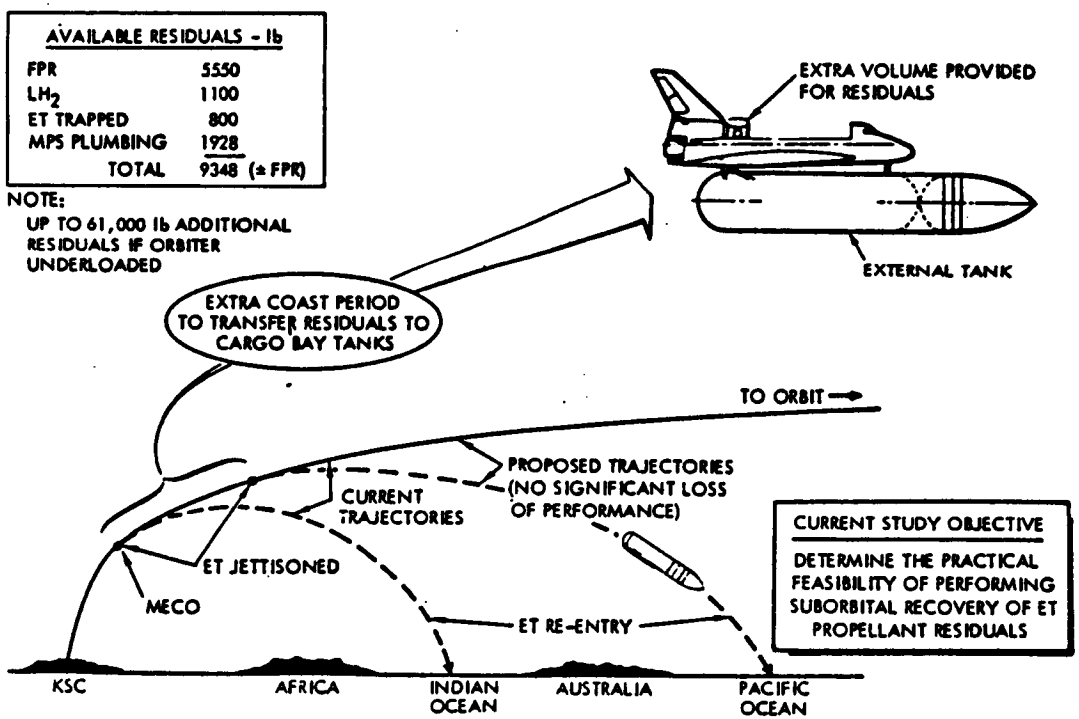
FIGURE 3.1 ET RESIDUALS RECOVERY CONCEPT



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FLUIDS MANAGEMENT METHODS/TECHNIQUES

- BULK FLUID TRANSFERS FOR SUBSEQUENT USE IN CONSUMING SYSTEMS
  - ET SCAVENGING - RCS OR OMS SETTLING (10^{-3} TO 10^{-2}G)
  - ON-ORBIT TRANSFERS/LEO - (10^{-5} TO 10^{-4}G)
    - FULL VESSEL/EMPTY VESSEL EXCHANGE
      - VESSELS ONLY
      - AS PART OF WHOLE STAGES OR MODULES
    - VESSEL TO VESSEL FLOW
      - DYNAMIC TECHNIQUES
        - VEHICLE MANEUVER
        - INTERNAL DEVICE
      - PASSIVE TECHNIQUE
        - DIAPHRAGM/BELLOWS
        - CAPILLARY CHANNELS OR VANES
        - CAPILLARY SCREENS

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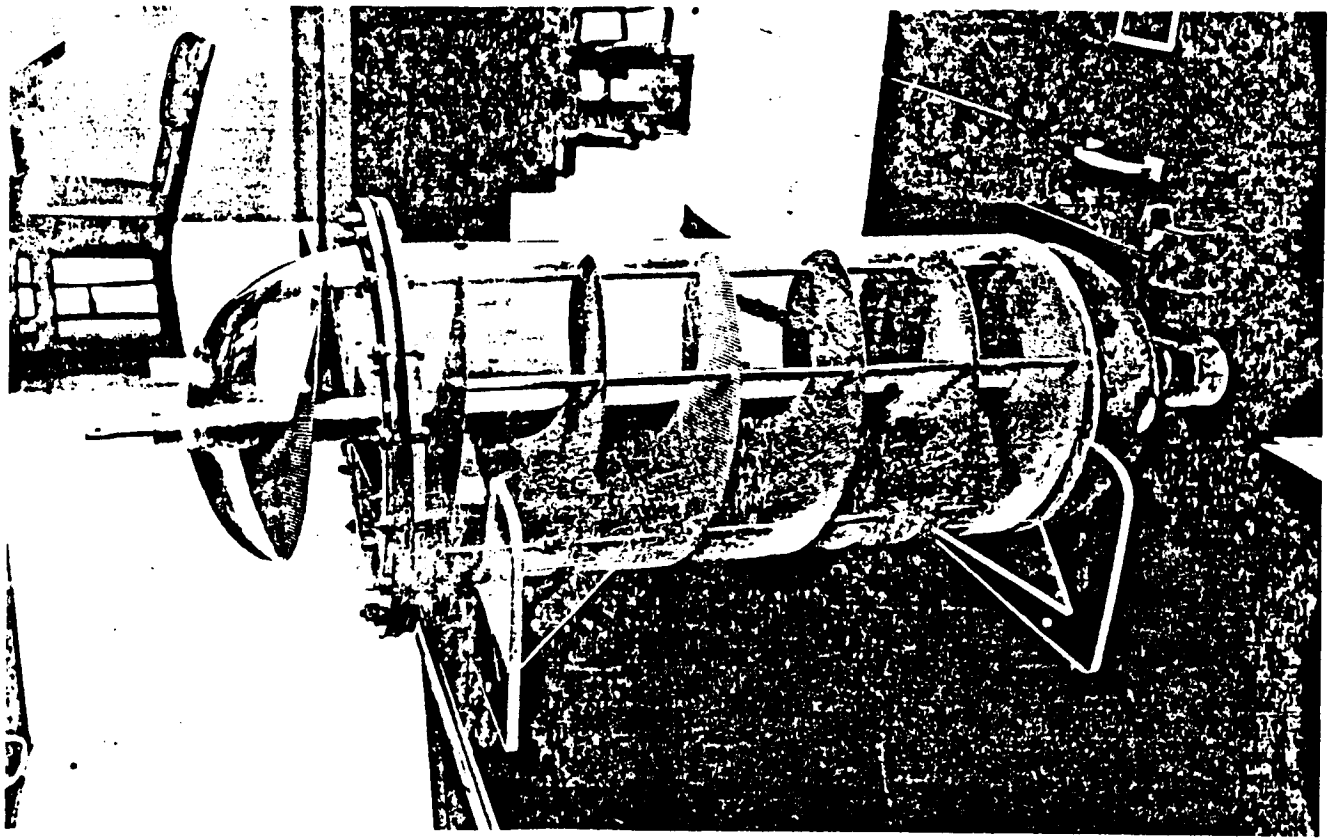
MECHANICALLY INDUCED SETTLING TECHNOLOGY (MIST)



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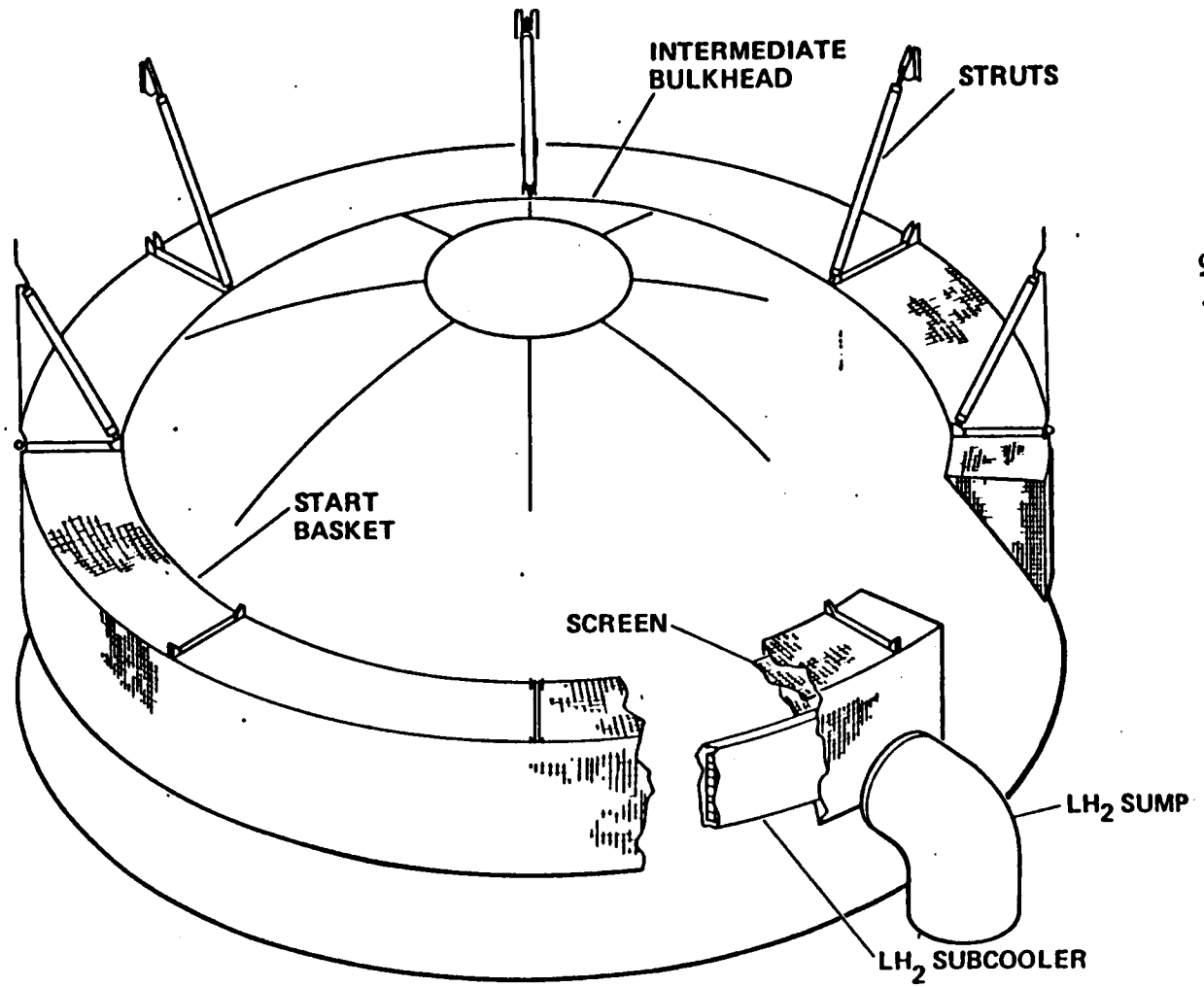
LH_2 START BASKET



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FLUIDS MANAGEMENT METHODS/TECHNIQUES (CONT'D)

- VESSEL OUTFLOW TO CONSUMING SYSTEMS
  - SUPERCRITICAL CRYOGENICS
  - LIQUID DELIVERY FROM TWO PHASE FLUID
    - DYNAMIC TECHNIQUES
      - INTERNAL DEVICES
    - PASSIVE TECHNIQUES
      - DIAPHRAGMS/BELLOWS
      - CAPILLARY CHANNELS OR VANES
      - CAPILLARY SCREENS
  - GAS DELIVERY FROM SUBCRITICAL CRYOGENIC FLUIDS
    - JOULE-THOMPSON, VAPOR COOLED SHIELD

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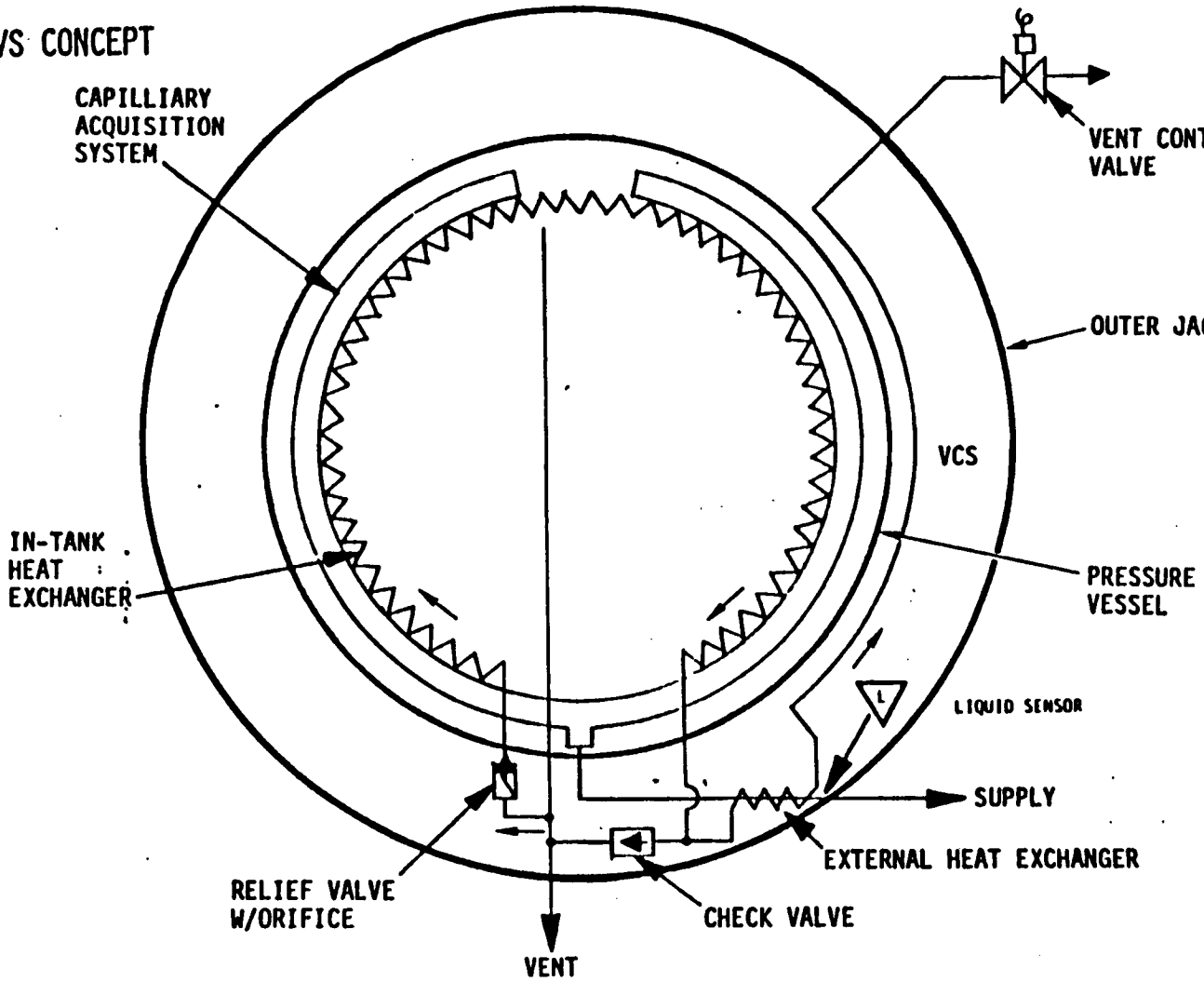
ROCKWELL TVS CONCEPT



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FLUIDS MANAGEMENT METHODS/TECHNIQUES (CONT'D)

- LONG TERM STORAGE OF CRYOGENICS
  - SINGLE WALL, ISOLATION MOUNTS, MULTILAYER INSULATION, VAPOR COOLED SHIELDS
  - DEWARS
  - ACTIVE REFRIGERATION
    - BOILOFF PREVENTION
    - TRANSFER BOILOFF RECOVERY
    - SUBCOOLING OF PROPELLANTS
- QUANTITY MEASUREMENT
  - RADIO FREQUENCY
  - NUCLEONIC
  - ACOUSTIC CAVITY/ULTRASONIC
  - MECHANICAL SETTLING/LEVEL SENSORS
  - ACCUMULATIVE FLOW
  - PRESSURE, VOLUME, TEMPERATURE

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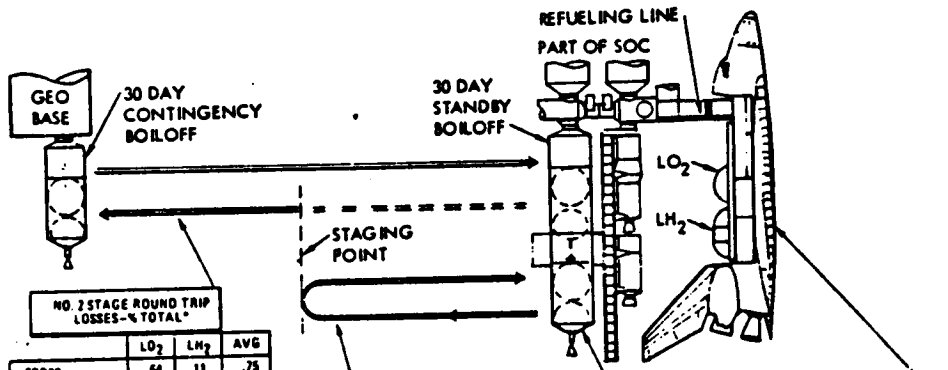
BASELINE CRYO PROPELLANT LOSS MODEL (MOTV/SOC/ORBITER)



NO. 2 STAGE ROUND TRIP LOSSES-% TOTAL*

	LO_2	LH_2	AVG
FPR**	.64	11	.75
FUEL BIAS	—	10	10
BOILOFF	20	20	.40
LIQ TRAPPED	45	05	.50
VAP TRAPPED	17	13	.30
TOTAL	1.46	59	2.05

GRAND TOTAL	4.91	2.39	7.3

NO. 1 STAGE ROUND TRIP LOSSES-% TOTAL*

	LO_2	LH_2	AVG
FPR**	.64	11	.75
FUEL BIAS	—	10	10
BOILOFF	—	—	—
LIQ TRAPPED	45	05	.50
VAP TRAPPED	17	13	.30
TOTAL	1.26	39	1.65

SOC/MOTV LOSS-% TOTAL*

	LO_2	LH_2	AVG
LINE CHILL	06	84	.90
MOTV CHILL	—	30	30
BOILOFF	40	40	80
TOTAL	46	74	1.20

ORBITER LOSS-% TOTAL*

	LO_2	LH_2	AVG
LIQ TRAPPED	1.45	45	1.9
VAP TRAPPED	.28	.22	.5
TOTAL	1.73	.67	2.4

-*% OF TOTAL PROPELLANT LOADED ON GROUND

**FLIGHT PERFORMANCE RESERVE

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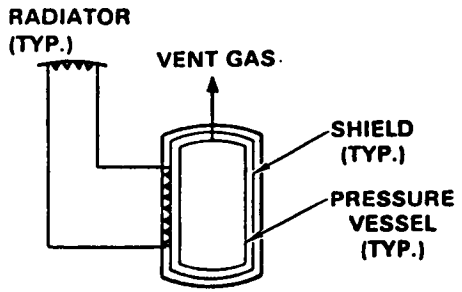
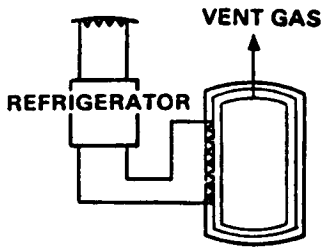
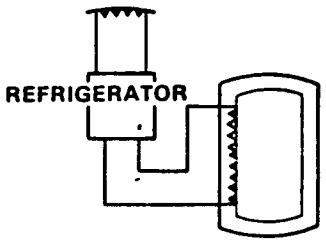
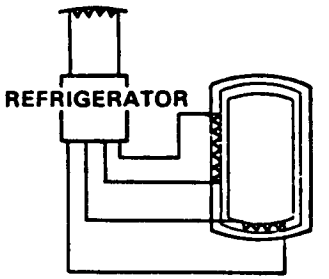
CRYOGENIC FLUID STORAGE
ACTIVE THERMAL CONTROL CONCEPTS



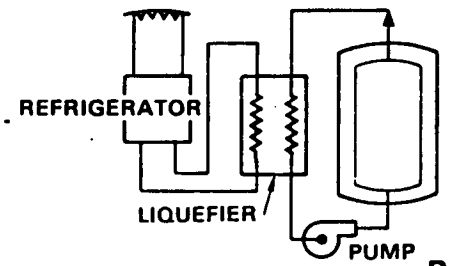


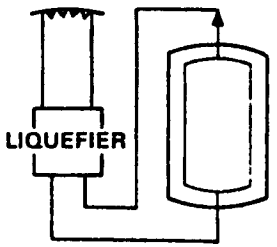
COOLED SHIELD





COOLED PRESSURE VESSEL





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FLUIDS MANAGEMENT METHODS/TECHNIQUES (CONT'D)

- QUALITY MEASUREMENT
  - LIQUID SENSORS - VAPORS DETECTION ONLY
  - MASS FLOW METER
- FLOW MEASUREMENT
  - MASS FLOW METER
  - STANDARD TECHNIQUES

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NASA FUNDED PROGRAMS

- CRYOGENIC FLUID MANAGEMENT FACILITY - ORBITER PAYLOAD BAY EXPERIMENT (LeRC)
  - LIQUID HYDROGEN ON-ORBIT TRANSFER
    - SUPPLY DEWAR
    - SINGLE WALL RECEIVER (OTV SUBSCALE)
  - QUANTITY, QUALITY, FLOW METER TESTBED
- QUANTITY METER DEVELOPMENT (JSC)
- OTV TANKAGE DEVELOPMENT (MSFC)
- MECHANICALLY INDUCED SETTLING TECHNOLOGY (MIST-JSC)

FUTURE PROGRAMS

- ET SCAVENGING TECHNOLOGY
- MASS FLOW METER DEVELOPMENT

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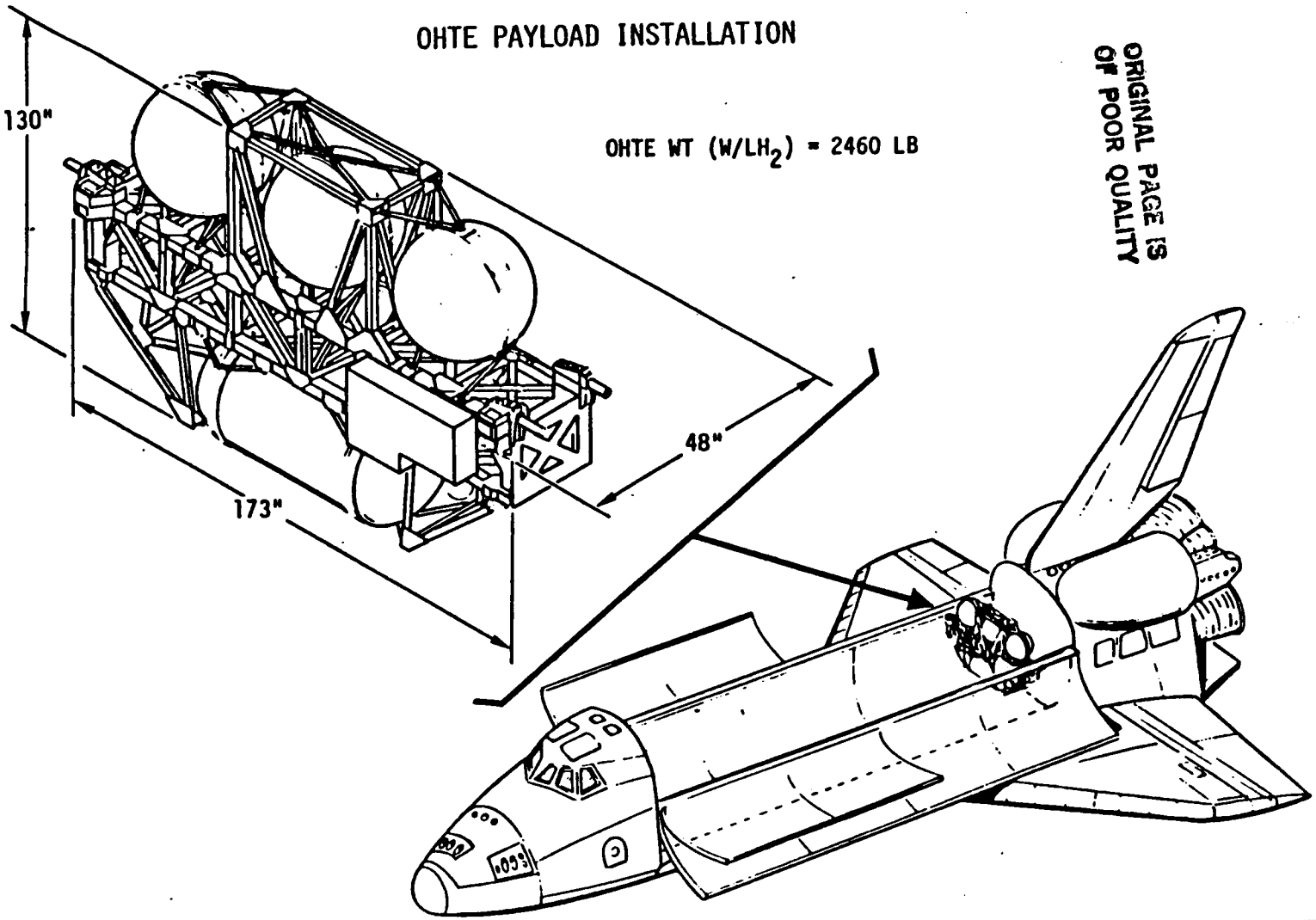
OHTE PAYLOAD INSTALLATION



OHTE WT (W/LH_2) = 2460 LB

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